UNIVERSITI PUTRA MALAYSIA

A COMPARISON OF LINEAR AND UNDULATING PERIODIZATION FOR IMPROVING MUSCULAR STRENGTH AND STRENGTH ENDURANCE IN MEN

SABA NIKNAFS

FPP 2008 32

A COMPARISON OF LINEAR AND UNDULATING PERIODIZATION FOR IMPROVING MUSCULAR STRENGTH AND STRENGTH ENDURANCE IN MEN

By

SABA NIKNAFS

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

September 2008

Dedications

To my parents

Motahareh and Ali

For their love, generosity, and guidance

through all my years.

To my Brother

Nima

For his undying devotion

and endless support.

To my Dear Uncles

Pedram and Ziya

For supporting and encouraging me

throughout my study.

Abstract of thesis presented to the senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

A COMPARISON OF LINEAR AND UNDULATING PERIODIZATION FOR IMPROVING MUSCULAR STRENGTH AND STRENGTH ENDURANCE IN MEN

By

SABA NIKNAFS

September 2008

Chairman: Kok Lian Yee, PhD

Faculty: Faculty of Educational Studies

The purpose of the study was to determine if significant differences exist between two different periodization programs (linear and undulating), in eliciting superior gains in maximum strength and strength endurance for the back squat and bench press. Twenty (n=20) sports science university students underwent a 15-wk resistance-training program. They were tested for the one-repetition maximum (1RM) back squat, 1RM bench press, upper-body strength endurance (80% 1RM bench press), lower-body strength endurance (80% 1RM back squat), body-fat percentage, power (Wingate test), thigh and arm circumferences, and changes in body mass. Following initial testing, participants were randomly assigned to either linear periodization (LP) or undulating periodization (UP) training. Participants performed both the bench press and the back squat three days a week throughout the training period with volume and intensity

equated for both groups at the end of training. The LP group linearly changed intensity and volume over each 4-wk training phase, while the UP group changed intensity and volume daily. Participants were then re-tested at the end of each 4-wk training phase and training loads were then adjusted according to the new 1RM. Repeated measures ANOVA were conducted to examine differences between groups. Maximum strength and strength endurance for both bench press and back squat increased significantly from pre to post test for both groups (bench press maximum strength increased from 50.5 kg to 62.8 kg and 50.3 kg to 61.5 kg for LP and UP groups respectively and bench press strength endurance increased from 5.5 repetitions to 10.6 repetitions and 6.2 repetitions to 11.2 repetitions for LP and UP groups respectively). However, there was no significant difference in pre-post strength and strength endurance measures in the LP group compared to the UP group. Each of the two models proved effective in increasing bench press and back squat strength and strength endurance over the course of fifteen weeks.

Abstrak tesis yang dikemukakan kepada senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PERBANDINGAN ANTARA PROGRAM PERIODISASI LINEAR DAN UNDULATING UNTUK PENINGKATAN KEKUATAN SERTA DAYA TAHAN OTOT DI KALANGAN LELAKI TIDAK TERLATIH

Oleh

SABA NIKNAFS

2008

Pengerusi: Kok Lian Yee, PhD

Fakulti: Pengajian Pendidikan

Tujuan kajian ini adalah bagi mengenalpasti samada wujud perbezaan yang signifikan di antara dua program periodisasi (*linear* dan *undulating*) dalam meningkatkan kekuatan otot maksimum serta daya tahan otot bagi senaman *back squat* and *bench press*. Seramai 20 (n=20) subjek yang merangkumi mahasiswa-mahasiswa universiti dalam jurusan sains sukan yang telah melalui program latihan bebanan selama 15 minggu. Subjek telah diuji melalui *one-repetition maximum* (1RM) *back squat*, 1RM *bench press*, daya tahan bahagian atas badan (80% 1RM bench press), daya tahan bahagian bawah badan (80% 1RM back squat), peratus lemak dalam badan, kuasa (ujian Wingate), ukuran lilit bahagian peha, lengan, pinggul dan pinggang, dan perubahan berat badan. Setelah melalui ujian awalan, subjek seterusnya dipilih secara rawak bagi program periodisasi *linear* ataupun *undulating*. Subjek telah melakukan

latihan *bench press* dan *back squat* tiga kali dalam seminggu sepanjang program latihan dengan isipadu serta intensiti latihan disamakan pada akhir program latihan. Program periodisasi *linear* berubah isipadu serta intensiti setiap empat minggu menurut fasa, manakala program periodisasi *undulating* pula berubah isipadu serta intensiti setiap hari. Subjek telah diuji selepas setiap empat minggu latihan, dan beban latihan mengikut diubahsuai nilai 1RM yang baru. Pengukuran berulang ANOVA telah digunakan bagi memastikan perbezaan di antara kumpulan kajian tersebut. Nilai kekuatan maksimum serta daya tahan bagi kedua-dua *bench press* and *back squat* didapati bertambah secara signifikan daripada pra ke pasca ujian bagi kedua-dua kumpulan (*bench press* maksimum bertambah dari 50.5 kg kepada 62.8 kg dan 50.3 kg kepada 61.5 kg bagi kumpulan LP dan UP masing-masing, manakala *bench press* daya tahan bertambah dari 5.5 ulangan kepada 10.6 ulangan dan 6.2 ulangan kepada 11.2 ulangan bagi kumpulan LP dan UP masing-masing). Namun, tiada perbezaan yang signifikan di antara pengukuran pra-pasca kekuatan otot maksimum serta daya tahan otot kumpulan dalam program periodisasi *linear* (LP) berbanding dengan program periodisasi *undulating* (UP). Selain itu, kedua-dua model yang digunakan adalah berkesan untuk peningkatan kekuatan dan daya tahu *bench press* dan *back squat* sepanjang 15 minggu program tersebut berjalan.

ACKNOWLEDGEMENTS

I would like to thank my graduate supervisor, Dr. Kok Lian Yee. This study could not have been completed without her thorough supervision. Dr. Kok, thank you for putting so much thought and energy into the construction of the whole study in terms of your extremely broad expertise and knowledge, and more importantly, your ongoing assistance, encouragement as well as very valuable comments.

I greatly appreciate the generous help and support from Prof. Iraj Malek Mohammadi. He helped me over the entire study period especially with the start of my thesis. I could not have completed this study without his encouragement and help.

I am practically indebted to my dear friend Dr. Darioush Moflehi, who was very helpful during data collection. Darioush, thank you for your endless support throughout my study. Your support and valuable comments made this study possible.

I certify that an Examination Committee has met on 25 September 2008 to conduct the final examination of Saba Niknafs on his Master of Science thesis entitled "A Comparison of Linear and Undulating Periodization for Improving Muscular Strength and Strength Endurance in Men" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the Master of Science.

Members of the Examination Committee were as follows:

Saidon bin Amri, PhD
Lecturer
Faculty of Educational Studies
Universiti Putra Malaysia
(Chairman)

Chee Chen Soon, PhD
Lecturer
Faculty of Educational Studies
Universiti Putra Malaysia
(Internal Examiner)

Tengku Fadilah Bt Tengku Kamalden, PhD
Lecturer
Faculty of Education
Universiti Putra Malaysia
(Internal Examiner)

Oleksandr Krasilshchikov, PhD
Lecturer
School of Medical Science
Universiti Sains Malaysia
(External Examiner)

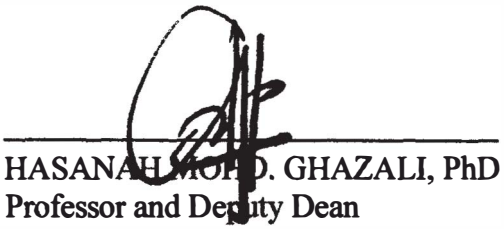
HASANAH MOHD. GHAZALI, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 27 November 2008

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The Members of the Supervisory Committee were as follows:

Kok Lian Yee, PhD
Lecturer
Department of Sports Studies
Faculty of Educational Studies
Universiti Putra Malaysia
(Chairman)

Soh Kim Geok, PhD
Associate Professor
Department of Sports Studies
Faculty of Educational Studies
Universiti Putra Malaysia
(Member)



HASANAH MOHD. GHAZALI, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 22 December 2008

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not currently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

SABA NIKNAFS

Date:

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

Introduction

Hypertrophy, maximal strength, power, rate of force development and strength endurance are some of the strength qualities that many athletes are required to possess in order to excel in their sports. The major goal of hypertrophy is to increase adaptation to resistance and muscle mass (Bompa, 1999). Maximum strength refers to the highest force the neuromuscular system can perform during a maximum voluntary contraction and is demonstrated by the highest load that an athlete can lift in one attempt (Bompa, 1999), while power has been defined as force multiplied by velocity (Marandino, 2002). Strength endurance is the muscle's ability to sustain work for a prolonged time. It represents the product of stressing both strength and endurance in training (Bompa, 1999). It has been suggested that the training of the strength qualities mentioned above be arranged according to periodization theory (Bompa & Carrera, 2005). According to this theory, after general adaptation or preparation phase, the initial phase of strength training is the hypertrophy phase, which emphasizes high volume and low resistance. This is followed by the maximal strength and conversion phases when strength is converted to power, power endurance or strength endurance or combination of any of these qualities (Bompa & Carrera, 2005). The major goal of these phases is to stimulate increases in maximal strength and power, power endurance or strength endurance (Pearson, Faigenbaum, Conley & Kraemer, 2000). It is thought that without the conversion phase, athletes cannot maximize their potential for the benefit of increasing sports performance (Bompa & Carrera, 2005).

In the development of strength qualities, maximal strength is improved through the maximum load method, which is maximum load could be used for completing the reps in maximum strength phase (4-8 reps), and it is probably the most important determinant factor in developing specific strength in a particular sport (Bompa, 1999). Fleck and Kraemer (1997), and Tan (1999) concluded that a range of two to five sets or three to six sets (respectively) promotes the greatest increases in strength. Volume assignments for power training are typically lower than those for strength training to maximize the quality of exercise. This reduction in volume is due to fewer repetitions and light loads. The common guideline is three to five sets (after warm-up) for power exercises (Baechle & Earle, 2000). Resistance training programs that emphasize strength endurance involve performing many repetitions, more than 20 to 30 repetitions per set (Foran, 2001).

Training may enhance an athlete's ability to exercise with less rest; an endurance training program has very short rest periods, often less than 30s, but athletes who seek to perform maximal or near-maximal repetitions with a heavy load usually need long rest periods. Common guidelines for the rest period length are at least two minutes or a range of 2-5 or 3-5 min for heavy loads (Baechle & Earle, 2000). Athletes who are interested in gaining muscular size often use a short to moderate rest period. Typical strategies for the length of rest periods are less than 1min 30 seconds or a span of 30s to 1 min, or 30s to 1min 30 seconds (Baechle & Earle, 2000). The length of rest periods are less than 5 min between sets to achieve strength endurance (Foran, 2001), however

the length of rest periods in short and medium duration methods are between 60 and 90 seconds and 2 min respectively (Bompa & Carrera, 2005).

All the training variables above are usually programmed according to one of the most important developments in the technology of sports training that is, the periodization of training. Using periodization, an athlete can vary the program either within a week (nonlinear or undulating periodization, UP) or over a number of training cycles (linear periodization, LP). The linear model is the most classic model of periodization with training emphasizing a strength component over a few weeks before changing to another component. Therefore, with more frequent completion of an entire training cycle within a year, greater gains appear possible because of increased variation. However, many athletes have started to use the UP model of nonlinear periodization in which more dramatic changes occur within a week-long training cycle that is a different strength component emphasized each day. The efficacy of either periodization model over the other has not been conclusive.

Statement of Problem

Previous research comparing LP and UP have reported no significant differences between LP and UP programs (Baker, Wilson & Carlyon, 1994; Rhea, Phillips, Burkett, Stone, Ball, Alvar et al., 2003), while one has found that UP is better for strength development (Rhea, Ball, Phillips & Burkett, 2002) and the other has found that LP is better (Hoffman, Wendell, Cooper & Kang, 2003). However the efficacy of one model

over the other still needs investigation and no study was found to have investigated strength endurance gains in upper- and lower-body between LP and UP training.

Research Objectives

The main objective in this research is to compare linear with nonlinear periodization in the development of strength qualities such as maximal strength and strength endurance in male university students.

Hypothesis

The main hypothesis is that there are no significant differences in muscular qualities such as maximal strength, strength endurance, power and hypertrophic responses between groups that trained with a LP training program compared to a UP training program. The sub-hypotheses were as follows:

I) There were no significant differences in maximal upper- and lower-body strength (1RM) between the two training groups, LP and UP, after the 12-wk training period.

II) There were no significant differences in upper- and lower-body strength endurance between the two training groups, LP and UP, after the 12-wk training period.

III) There were no significant differences in power between the two training groups, LP and UP, after the 12-wk training period.

IV) There were no significant differences in hypertrophic responses between the two training groups, LP and UP, after the 12-wk training period.

Limitations and Delimitations

The researcher faced several limitations and delimitations in the course of this study. These limitations stemmed from conditions that could not be controlled, or were the results of the delimitations that were imposed. The limitations and delimitations were as follows:

- This study is limited to comparing linear and undulating periodization training programs.
- Any changes or improvement in the variables tested was limited to the training frequency, intensity and duration set by the researcher.
- Although subjects had prior resistance training experience, this study was delimited to those who had not strength trained consistently (more than once per week) in the two months prior to the study.
- The other delimitation involves the representativeness of the sample, as only males between the ages of 19 - 24 were used as subjects.
- To maintain equal volume between subjects, this study was delimited to subjects who were performing no other resistance training concurrently.

Operational Definitions

Periodization: A systematic process of planned variations in a strength-training program over a training cycle with specific objectives of maximizing strength gains and avoiding overtraining syndrome. In this study all subjects did 3-wk preparation and then divided into two groups, LP and UP, then continue their training program for another 12 weeks.

Linear Periodization (LP): Periodization model that follows a general pattern of decreasing training volume and increasing training intensity over a series of microcycles; also known as the classical model. In this study the LP group followed a training of 4 wk of hypertrophy, followed by 4 wk of maximum strength training, before finishing with 4 wk of strength endurance training.

Undulating Periodization: Also known as non-linear periodization, this model calls for more frequent alterations in intensity and volume than the linear model. In this study, the UP group followed a training schedule where changes in volume and intensity were made on a daily basis. The details of the training schedule were as followed (that is) hypertrophy training on Saturday, max strength training on Monday, and strength endurance training on Wednesday, to improve strength qualities during 12-wk training period.

Hypertrophy: Enlargement of muscle fibers due to trauma to muscle (stemming from muscular overload) followed by a period of regeneration causing an increase in the

cross-sectional area of the fibers. In this study it was measured through circumference changes in thigh and arm.

Maximum Strength: Maximal amount of force a muscle or muscle group can generate in a specified movement pattern at a specified velocity. It was measured by 1 repetition maximum test for upper-body (bench press) and lower-body (back squat) in this study.

Strength Endurance / Muscular Endurance: The muscle's ability to sustain work for a prolonged time (Bompa, 1999). It was measured by determining the number of repetitions lifted at 80% of the 1RM until they reached total failure for upper-body (bench press) and lower-body (back squat).

Non Resistance-trained: According to Baker et al. (1994) and Schiotz et al. (1998), subjects who could perform squats with loads between 1.2 and 1.5 times their body mass, and bench press approximately 1.1 times their body mass, were categorized as moderately trained. In this research, since the subjects performed bench press and back squat 0.70 and 1.17 times their body weight respectively, they were considered upper- and lower-body untrained.

Importance of the Study

As the efficacy of either LP or UP over the other is still inconclusive, one of the importance of this study would be to perform another comparison between the two models. This would help demonstrate if either periodized model is effective for

improving the different strength qualities in untrained but active male sports science students. As previous studies on periodization have usually examined maximal strength development (Baker et al, 1994; Hoffman et al, 2003; and Rhea et al, 2002), and only one on lower-body strength endurance (Rhea et al, 2003), this study may be the first to examine the effect of periodization on lower- and upper-body strength endurance. This is an important factor as players who are in strong physical shape, are more able to compete and battle during a game, less prone to injury, and tend to make the lineup on a regular basis compared to weaker players (Pollitt, 2004). In addition, preliminary evidence also indicates that resistance training may increase athlete's resistance to sports-related injuries (Pearson et al., 2000).

Chapter 2

Literature Review

This chapter will lay out the theoretical dimensions of the research, and will offer the definitions of the various strength qualities. There will also be a discussion on the development of strength qualities, including the use of periodization for improving strength and strength endurance.

Definition of Various Strength Qualities

Strength has been described as the ability to produce maximal force (Kraemer & Fleck, 2005). Strength is a key factor for the prevention of injury and also physical performance. The gain in strength is usually linked to the enlargement of muscle which is also known as hypertrophy. Hypertrophy is a phenomenon that is due to an increase in the cross-sectional area of individual muscle fibers. Individuals who undergo resistance training will experience two kinds of hypertrophy. The first type of hypertrophy is called short-term hypertrophy that long lasts only for a few hours and is the result of the pump experienced during heavy training, and the other is chronic hypertrophy which is due to structural changes at the muscle level (Bompa, 1999).

Maximum strength is the highest force which the neuromuscular system can perform during a maximum voluntary contraction. This is revealed by the highest load that an athlete can lift in one attempt (Bompa, 1999) and it is usually determined through the

measurement of a maximal lift called one-repetition maximum (1RM). The maximum strength is related to the biomechanical characteristics of a movement and the amount of contraction of the muscles involved.

Power is the ability of the neuromuscular system to produce the greatest possible force in the shortest amount of time. Power defines as product of muscle force multiplied by the velocity of movement (Marandino, 2002; McCarthy & Wisconsin 2003). As mentioned above, any increase in power must be the result of improvements in either strength, speed or a combination of the two (Bompa, 1999).

Strength endurance defines as the ability of muscle to maintain work for a prolonged time (Bompa, 1999). It is best increased through a strength training program that emphasizes a high number of repetitions performed at a steady pace. Different types of strength endurance training include dynamic concentric-eccentric activities such as rowing, swimming, cycling, cross-country skiing, canoeing, kayaking, rugby, racket sports and boxing, and isometric activities like in sports that the athletes need to remain in a specific position for several minutes (e.g. sailing and driving). Also, in some mixed endurance activities there are combination of dynamic and isometric movements such as shooting and archery. Duration of strength endurance activities can be short, medium or long (Bompa & Carrera, 2005).

A combination of strength and speed creates power, while combining strength and endurance produced strength endurance (refer figure 2.1). Strength, speed and